1940

The effect of insect control on the yield and quality of cotton prematurely killed by cotton root rot

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14

THE EFFECT OF INSECT CONTROL ON THE YIELD AND QUALITY OF COTTON PREMATURELY KILLED BY COTTON ROOT ROT

By

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A Thesis Submitted to the Graduate Faculty
for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject Entomology

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Iowa State College

1940

TABLE OF CONTENTS

INTRODUCTION

Cotton is by far the most important crop grown in Texas. The declining price in recent years and the losses due to insects and cotton root rot have made production unprofitable on many acres. It has been estimated that insects cause a loss of 10 to 15 percent of the Texas cotton crop, a loss amounting to millions of dollars annually. Root rot also causes enormous losses. These problems have stimulated research workers to study methods for increasing yields and improving the quality of cotton. Entomologists have been successful in finding economical methods for combating the boll weevil and cotton flea hopper, but more satisfactory methods are needed for controlling cotton root rot.

These investigations were made to determine if losses caused by root rot could be indirectly reduced by protecting the cotton from insect pests and thereby increasing the yield on plants prematurely killed. It was necessary to consider the development and fruiting habits of the cotton plant, insect injury, yield, and quality of cotton produced on plants killed by root rot.

The writer's objective was to determine the effect of controlling the flea hopper and boll weevil on the yield and quality of cotton lint and seeds from plants killed in various stages of development by root rot. Determining the value of insect control on living cotton was not considered except as a standard for comparison with dead plants.

HISTORICAL

Farmers are probably right in saying that cotton can promise more and produce less, or promise less and produce more, than any other crop. It can withstand a wide variety of environmental conditions and still be fairly productive. Cultural practices which favor a high yield one year may not be successful under different conditions another year. A few of the basic principles of cotton production must be discussed here in order to provide a clear interpretation of the results from these experiments.

Cotton Plant

The cotton plant has both vegetative and fruiting buds. Conditions such as thin spacing, fertile soil, ample soil moisture, destruction of fruiting forms by the flea hopper, and many others will stimulate growth of the vegetative buds, and a large plant will develop, which will be late in fruiting (Brown 1938). Since insects, root rot, and deficiency of soil moisture often damage a crop late in the season, it is desirable to suppress the vegetative buds and to force the development of fruiting buds early in the season. Delayed thinning until the plants are 8 to 10 inches tall (Cook 1932), or leaving a thick stand, will reduce vegetative growth and hasten maturity (Cook 1931). Reynolds (1926) found that the highest yields were produced by medium spacing. The early maturing varieties are also the higher producing varieties (Killough, Dunlavy, and Rea 1929).

The life cycle of a cotton form (fruit) depends on several factors, but is approximately as follows: square 25 to 30 days, bloom 1 day, and boll 45 to 55 days (Hubbard 1931, Buie 1929, and McNamara, Hubbard, and Beckett 1927). Under favorable conditions, fruiting begins at about 7 weeks after planting (Buie 1929). According to these figures, and depending on a wide variety of conditions, there is a minimum of about 110 days from the time cotton is planted until the first bolls open.

The cotton fiber is formed from the elongation of a single epidermal cell (Brown 1938). The cell elongates rapidly for the first 25 to 30 days but has thin walls. During the remaining boll period the walls thicken, but the cell retains a cylindrical shape. This cell collapses upon drying out when the boll opens (Webb and Conrad 1935). The ash and protein percentage change little during the development of the seed. The oil increases rapidly during a period when the seed is about 32 days old, and slowly thereafter (Gallup 1928). Since growth in the fiber and seeds continues until the boll opens, the death of the plant before that time would stop the normal development.

The cotton plant normally sheds more than half the forms it sets. These consist of very small squares and young bolls. Shedding is usually most severe on heavily fruited plants when there is a deficiency of soil moisture (Hawkins, Matlock, and Hobart 1933). It sometimes happens that cotton dusted for insect control will fruit heavily and during dry weather shed so much fruit that the yield will be as low as cotton not dusted. Since cotton seldom sheds early in the season, flea hopper damage is of greater importance at that time than after a crop has been set (fig. 1).

Cotton should be picked shortly after the bolls open. Nickerson (1932) found that exposure of more than two weeks after a boll opened lowered its quality. This may account, in part, for the low quality in cotton from plants killed by root rot, since the bolls open earlier than those on living plants, and therefore would be exposed longer. If the cotton is allowed to be exposed to the weather for six weeks or longer, the value may be decreased by 50 cents to $2.00 per bale (Phagan and Pritchard 1937).

The price received for cotton depends largely on the quality, but Paulson and Hembree (1934) state that growers are not sufficiently rewarded for producing high quality cotton. Meadows and Blair (1923) report that uniformity of the fibers is the first essential of high quality in cotton fiber. The importance of uniformity is further stressed by Gerdes and Bennett (1939). Since cotton from plants killed by root rot is of variable grade and staple, it is impossible to secure a uniform bale (Ezekiel and Taubenhaus 1934).

The average cost, including rent, of cotton production in Texas in 1933 was $16.57 per acre or 8.6 cents per pound of lint (Anon. 1935). In 1930 the cost of production was 30 cents per pound on those acres producing 100 pounds or less; while on those producing 420 pounds, the cost was only 8 cents a pound (Anon. 1932). The profit depends largely on the yield obtained.

Fig. 1. Cotton flea hopper adult and scar from blasted square (greatly enlarged).

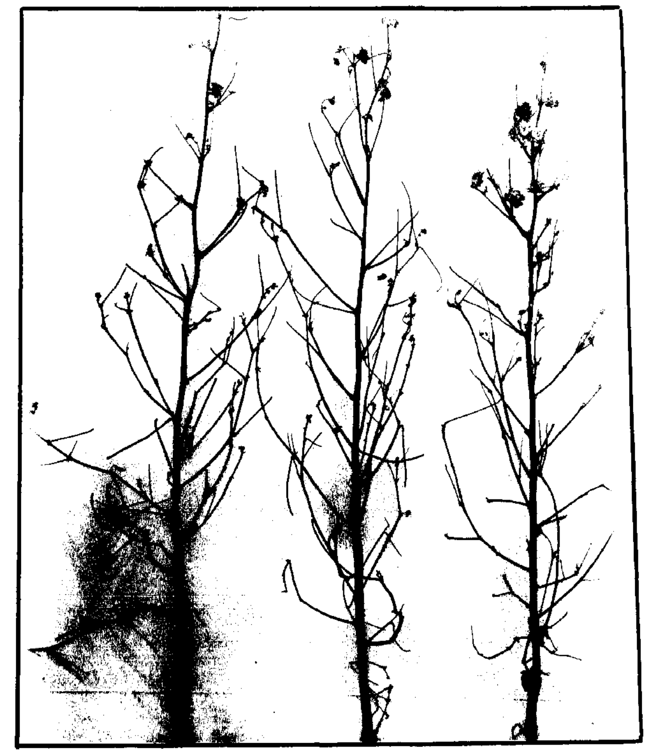

Fig. 2. Cotton plants showing flea hopper injury. Note excessive branching, short internodes, and scarcity of fruit. (Leaves were removed before photographing.)

Cotton Flea Hopper

The cotton flea hopper was described by Reuter (1876) from specimens collected in Texas by Belfrage and named Atomoscelis seriatus Reuter. The name was changed to Psallus seriatus (Reuter) by Van Duzee (1916). The common name "cotton flea" was used by Hunter (1924), and "flea hopper" by the same author (1926). Knight (1926) called it the "cotton flea hopper" and published a description of the species. He stated that it was known to occur from coast to coast and from Texas to Minnesota, and that the natural host was Croton. Jones (1927) reported Croton, horsemint, evening primrose, and cotton as important seasonal host plants in South Carolina. Reinhard (1927 and 1928) lists 54 food plants.

Overwintering eggs are principally deposited in the tissue of Croton. They hatch during the early spring months. The time of hatching and the condition of cotton during the peak of emergence has an important bearing on the extent of damage which follows (Reinhard 1928). Gaines (1933) found that fall rains which promoted Croton growth were important factors in determining the number of overwintering eggs.

Thomas (1936) states that, "As long as the soil moisture is sufficient to produce a tender or succulent growth the flea hoppers will continue breeding in the cotton, but as soon as dry weather causes the growth to slow up the infestation decreases."

The cotton flea hopper causes the blasting of young squares, swellings or lesions on the stems and petioles, and malformation of the leaves (fig. 2). McGarr (1933) found that the adult is slightly more injurious than the nymphs. Similar injuries may be caused by several other hemipterous and homopterous insects (McGarr 1933, Ewing and McGarr 1933, Ewing 1929, and King and Cook 1932). It was suspected by Hunter (1926) and Reinhard (1926) that the cotton flea hopper was the vector of a virus which caused these injuries. Painter (1930) saw cell inclusions which suggested the presence of an organism resembling a Myxomycete. He found that the inoculum did not move far from the point of injection, and that the systemic disturbance was due to the multiplicity of bites. King and Cook (1932) reported that injury was due to the injection of substances normally present in the insect's body, and not to the causative agent of a transmissible disease.

The first report of cotton flea hopper damage was made by Howard (1898) from observations made by John D. Mitchell near Victoria, Texas, in 1897. Reports from the same locality were again made in 1919 (Reinhard 1926), and investigations were started in the vicinity of Port Lavaca in 1923 (Hunter 1926), and at College Station the following year. Unusually severe damage was reported in 1926 when this pest was destructive over most of the cotton belt (Harned 1933), but only in that year did the flea hopper cause greater losses than did the boll weevil during the period 1909 to 1931. Reinhard (1926) makes the following statement:

"In the localities where the cotton flea hopper has demonstrated its ability to produce injury to the cotton crop, the unanimous opinion of growers has been that this insect is more destructive than the boll weevil."

The cotton flea hopper has been especially damaging in the Coastal Bend area in Texas. Investigations have been conducted at Port Lavaca almost every year since 1923. Ewing and McGarr (1937a) show graphically the infestation during the four years 1933 to 1936. Only in 1936 did the infestation fail to reach 50 flea hoppers per 100 terminal buds.

Sulfur dust was found to be effective in controlling this pest by Hunter (1925) and Reinhard (1926). Thomas (1936) recommends applications of sulfur dust at the rate of 12 to 20 pounds per acre, beginning early in the season when it is evident that flea hoppers are causing excessive shedding. He states that dusting costs for the season have varied from $2.00 to $4.00 per acre, and have provided net gains of $2.08 to $10.44 per acre. Ewing (1931) found that sulfur was much more toxic to nymphs than to adults, while mixtures of one-fourth paris green and three-fourths sulfur were more toxic to adults than to nymphs. Mixtures of paris green and sulfur, and calcium arsenate and sulfur have been used in tests by Ewing and McGarr (1936, 1937b, and 1938). They (1938) made the following recommendations:

"Where the flea hopper is the only injurious insect present and the infestation is heavy or a large proportion of the population consists of adults, a mixture of calcium arsenate and sulphur gives better and quicker control than sulphur alone. Sulphur alone should be used only for light infestations of flea hoppers or when the infestation consists principally of nymphs. Dusting for the flea hopper should begin when cotton fails to 'set' the small squares or when as many as 15 to 25 flea hoppers are present per 100 terminal buds."

Boll Weevil

The boll weevil (*Anthonomous grandis* Boh.) is the most destructive insect in the United States, according to Hyslop (1930). He states that the damage over a 19 year period amounted to 11.59 percent of the crop or an annual loss of $164,500,000. Investigations have been made on this pest since its introduction into this state in 1892. A review of 15 years of study on the effectiveness of calcium arsenate dusting for the control of the boll weevil was published by Young (1935). He reported that increases in yield resulted from the control of this insect every year. Largest increases were made during wet years when the damage was most severe. He also reported that with late seasonal infestations, more cotton was made on both the dusted plats and the checks.

Many publications on boll weevil control have been issued during the past 25 years by the state agricultural experiment stations, extension services in the cotton belt, and by the United States Department of Agriculture. Calcium arsenate dust is recommended for boll weevil control in Texas (Thomas, Owen, Gaines, and Sherman 1929).

Cotton Root Rot

The causative agent of cotton root rot (*Phymatotrichum omnivorum* (Duggar) Shear) was found by Pammel (1888) to be a fungus which attacks the roots. He was of the opinion that insects were not vectors (Pammel 1888 and 1889). Taubenhaus and Christenson (1934 and 1936) gave further proof that insects were not distributing agents of the fungus. It attacked 1,708 of 2,116 plants tested by Taubenhaus and Ezekiel (1936).

Cotton plants attacked by root rot show no symptoms of infection until they suddenly wilt and die (fig. 3). Plants attacked when the soil moisture is low, however, may turn yellow and die slowly. In some cases, new roots may appear near the surface of the ground and the plant revive, only to die when moisture conditions are more favorable for the fungus. The leaves turn brown and have a temperature of 2 to 5 degrees F. higher than normal, due to a lack of water for cooling by transpiration (Streets 1937).

Cotton root rot occurs in Texas, Louisiana, Arkansas, Oklahoma, New Mexico, Arizona, Utah, Nevada, California, and in Mexico. It is present in 196 of the 254 Texas counties (Streets 1937). The amount of infection depends on the presence of the causative organism, soil moisture and temperature (Taubenhaus and Dana 1928). Ezekiel (1938) found that the disease was not prevalent in sections of Texas with a mean normal temperature below about 60 degrees F. Fraps and Fudge (1935) state that a soil which contains appreciable amounts of lime and is slightly alkaline, of good fertility, and a loam or clay in texture is favorable to root rot. The disease thrives best in soils with pH 7 (Taubenhaus, Ezekiel, and Killough 1928). However, root rot is seldom found in alluvial soils in river or creek bottoms. Ratliffe (1934) determined the seasonal abundance of the disease over a 21 year period at San Antonio, Texas. He found that 2 percent of the cotton plants were killed during the period June 1 to 15, and by October 31, 48 percent had died. The number of root rot plants increased gradually, with the highest percentage dying during the period July 1 to 15. The time of planting seeds does not affect the amount of

Fig. 3. Cotton plants in several stages of development when killed by root rot. Note living plant on left.

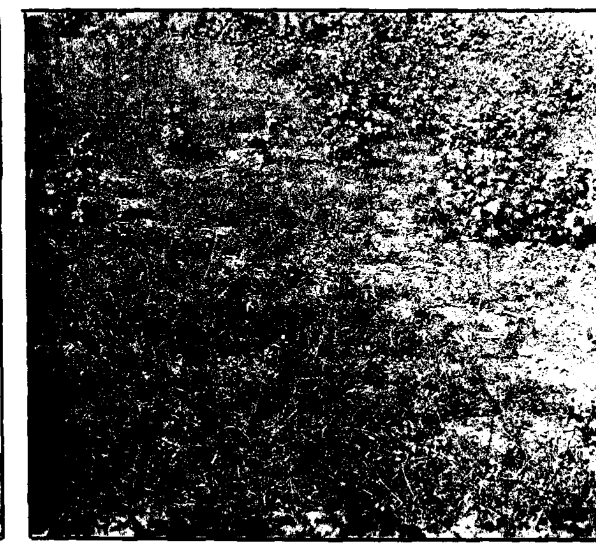

Fig. 4. Cotton field with large area of plants killed by root rot.

root rot except when done very late in the season (Conner 1929).

Entirely satisfactory control measures for cotton root rot have never been found. Pammel (1888) states that at that time planters were familiar with the fact that rotating cotton with non-susceptible crops reduced the amount of the disease. He further stated (1889) that rotations which allow three years without cotton were the only practical control. That recommendation is advised today (Rogers 1939). Rogers (1937b) states that, "Fair yields may be obtained in continuous cotton even under root rot conditions, provided the soil is in fertile condition, and, by chance, root rot is delayed until late season." Methods of increasing the yield of cotton from plants which are prematurely killed by root rot have been studied. One of the most important means of evading losses is to force maturity and thereby secure a partial crop before the plants are killed. This has been achieved by planting early maturing varieties (Streets 1937), thick spacing of plants (Cook 1931), by use of fertilizers (Jordan, Dawson, Skinner, and Hunter 1934), and by preventing insect injury (Rogers 1939).

The losses to all kinds of plants in Texas due to cotton root rot are estimated to be $100,000,000 annually (Neal 1933). Streets (1937) states that to cotton alone in this state the damage is estimated at 12 to 15 percent of the crop, with the greatest loss in any one year being $55,000,000 in 1920. Other crop reporters estimated that the losses due to all diseases during the period 1927 to 1936, inclusive, amounted to 2.7 percent of the Texas cotton crop (Anon. 1939). Ezekiel and Taubenhaus (1934) show the losses in 1928 by regions, and Ezekiel (1938) prepared a similar map of the losses in 1937. The losses vary with the portion of the plants which die and their stage of development when death occurs (Jordan, Dawson, Skinner, and Hunter 1934).

It was early recognized that cotton from root rot plants was of low quality (Pammel 1889). Several studies have been made on the yield and quality of cotton from plants prematurely killed by root rot. The exact date when the plants died was usually not determined, but the samples were from plants dying in the early-season, mid-season, or late-season. Campbell and Willis (1928) found that the yarn spun from lint produced on plants killed by root rot was weaker, of rougher appearance, and more wasty than that from living plants. Rogers (1936 and 1937a) found the protein content of the seeds was about the same from root rot as from living plants. The oil content, however, was reduced by premature death of the plants.

Ezekiel and Taubenhaus (1934) conducted studies on 646 plants killed at approximately weekly intervals by root rot, and on 235 plants which were living on September 10 when the first picking was made. They found that plants dying two months or more before the first picking produced an insignificant amount of cotton, while those dying five weeks before the harvest produced not more than half as much as living plants. The plants that died during the three weeks immediately preceding the first picking gave slightly higher yields than the living plants. They explain the fact that plants dying late in the season produced more cotton than those living on the following basis:

"(1) As root-rot spots enlarge during the season, these plants in the peripheral areas probably benefit from increased moisture and nutrient supplies made available as a result of lack of competition from the adjacent plants already killed by the disease. (2) More initial infections and also greater spread probably occur in the naturally moister parts of the field rather than in the naturally drier parts. Higher average yields would then be expected on surviving plants in the vicinity of root-rot spots because of the more favorable moisture conditions. The increased growth prior to infection is apparently more than sufficient to counterbalance the ill effects of late attack of root rot."

On the basis of these findings, they proposed the following method of estimating the crop losses from root rot:

"The data required for the first method are percentages of cotton plants killed by root rot at approximately 7 weeks and again at approximately 3 weeks before the date of first picking. Subtract the first percentage from the second, to find the percentage of plants that succumbed during 3 to 7 weeks before harvest, and divide this difference by 2. Add to the quotient the entire percentage of plants killed 7 weeks before harvest. The sum is the estimated total percentage reduction in yield."

Taubenhaus and Ezekiel (1935), in the experiment discussed above, found that root rot had little effect on the percentage of lint borne by plants prematurely killed, but that it was slightly higher on plants that died early in the season than on those dying later. The lint from plants which died three weeks or more before the first picking was one grade lower than that borne by plants dying later. They concluded that, while the quality of the lint was low, it was not of as much importance to the grower as the reduction in yield. Stroman, Taubenhaus, and Ezekiel (1935) found that fibers from plants killed early in the season had a wider ribbon width, were thicker, and had fewer convolutions than fibers from living plants.

EXPERIMENTAL

Method of Procedure

The data obtained in these investigations consisted of accurate yield records from plants killed by root rot at various intervals throughout the season, and yield records from normal living plants on plats where insects were controlled and also on untreated checks. The quality of the lint and seeds from each group of plants was determined in order that the yield from root rot plants could be evaluated.

Early in the season fields were selected where root rot was known to occur and where there was an incipient infestation of the flea hopper. Insects were controlled on one plat while on an adjacent plat no control was used. The plats used in 1937 were 30 rows wide and long enough to include one acre, with two rows separating the two plats. Two such plats were located in each of four fields that year. Plats consisting of 15 rows and long enough to include one-sixth acre were used in all later tests; and the dust and check treatments were replicated three or more times in each field in randomized blocks.

The flea hopper infestation was determined at weekly intervals by counting the nymphs and adults on 100 terminal buds. These records were made at three or more points in each plat. Dust applications were begun when 15 flea hoppers were found on 100 plants and were continued at weekly intervals as long as the infestation remained above that number. The boll weevil infestation was taken at 5 day intervals by examining 100 squares on successive plants for punctures. Three such records were made in the large plats and one in each of the smaller plats. Dust was applied at 5 day intervals for boll weevil control when the infestation was sufficient to puncture ten percent of the squares. The object was to secure the maximum flea hopper and boll weevil control regardless of the number of applications required.

The plats were examined at weekly intervals for plants killed by root rot (fig. 3). A plant was considered dead when the leaves had wilted and turned slightly brown. One row was taken at a time so that no dead plants would be overlooked. When a plant was dead, a dated paper shipping tag was attached near the top of the main stem. The week during which each plant died was thus definitely established. The plants were counted which were living at the time of the first picking.

The cotton from the dead plants was picked one or two days before the planter made his first picking in the rest of the field. The cotton from all plants which died during each week was put into a paper bag and weighed. All open bolls were picked from the dead plants regardless of size. A second picking was made from the dead plants about a week later to get the bolls which were not open at the time of the first picking. In this manner the yield per plant was secured from each group of root rot plants. The cotton was picked from the living plants and the yield per plant determined. Cotton from plants which died after the first picking was included with that from living plants, and no further records were made. The grower cultivated the plats in the same manner as the rest of the field.

The time of the first picking varies greatly in different areas, depending largely on the weather damage likely to occur when cotton is left in the field. The planters at Cameron, Texas, usually wait until about one-half the crop is open before making the first picking, while at Port Lavaca, Texas, tropical storms occasionally damage the crop and the first picking is made when about one-third of the bolls are open.

Materials

The sulfur dust used was 97 to 98 percent pure and ground so that 93 to 95 percent would pass through a 325 mesh screen. It contained 2 to 3 percent of a conditioning agent to aid in the dusting qualities. The calcium arsenate dust was a standard brand. The mixture of one-third calcium arsenate and two-thirds sulfur used in 1939 was prepared by one of the sulfur companies.

All dusts were applied between daylight and sunrise with a rotary hand duster.

1937 Results

Investigations were conducted at Cameron, Texas, during 1937. That location was selected because it is typical of a large cotton producing area where flea hoppers and root rot are usually destructive.

Crop conditions

The rainfall was below normal every month from February through July, with a total deficiency of 5.66 inches during the year (table 23). The soil moisture deficiency caused excessive shedding of small bolls late in the season. Losses due to insects and root rot were below normal.

Insect infestation

Two one acre plats were selected in each of four fields where root rot was known to occur and where there was an incipient flea hopper infestation already present. One plat was to be dusted for insect control and the other left undusted to serve as a check. Boll weevils were never destructive in any of the fields. The flea hopper infestation was sufficient to cause some damage during the first week observations were made. It decreased on all plats after about June 26, and no further damage was done (table 1).

Table 1. Effect of dusting on the cotton flea hopper infestation, 1937.

	Average number of cotton flea hoppers per 100 terminal buds							
Week	Field 1		Field 2		Field 3		Field 4	
ending	Check	Dust	Check	Dust	Check	Dust	Check	Dust
June 19	29	31	26	22	32	22	24	30
June 26	36	25	18	9	23	10	21	9
July 3	8	2	9	3	16	4	12	5
July 10	5	2	4	1	10	4	10	5
July 17	5	6	3	7	13	16	10	10
July 24	3	2	2	1	3	3	3	2
Weekly av.	14.3	11.3	10.3	7.2	16.2	8.2	13.3	10.2

Three applications of sulfur were made in each of two fields and two applications in the other fields (table 2). Although satisfactory control of the flea hopper was obtained, the infestation decreased on the check plats shortly after dusting was begun. The control of this small population was not sufficient to result in a material increase in yield.

Table 2. Date of dust applications and materials used, 1937.

Date dusted	Field 1	Field 2	Field 3	Field 4
June 19	Sulfur	Sulfur	--	--
June 22	--	--	Sulfur	Sulfur
June 25	Sulfur	Sulfur	--	--
June 29	--	--	Sulfur	Sulfur
July 3	Sulfur	Sulfur	--	--

Cotton root rot

Root rot was already killing plants by June 12. Records were made on 10,173 plants which died by August 14. Of this number only 5.66 percent died during the two weeks immediately preceding the first picking. The greatest loss in number of plants occurred during the weeks ending July 24 and 31 (fig. 5).

Results of insect control

The first picking was made during the week ending August 14. Yield records were not taken on the plants which were living at that time. The yield of seed cotton from root rot plants is given in table 3. These

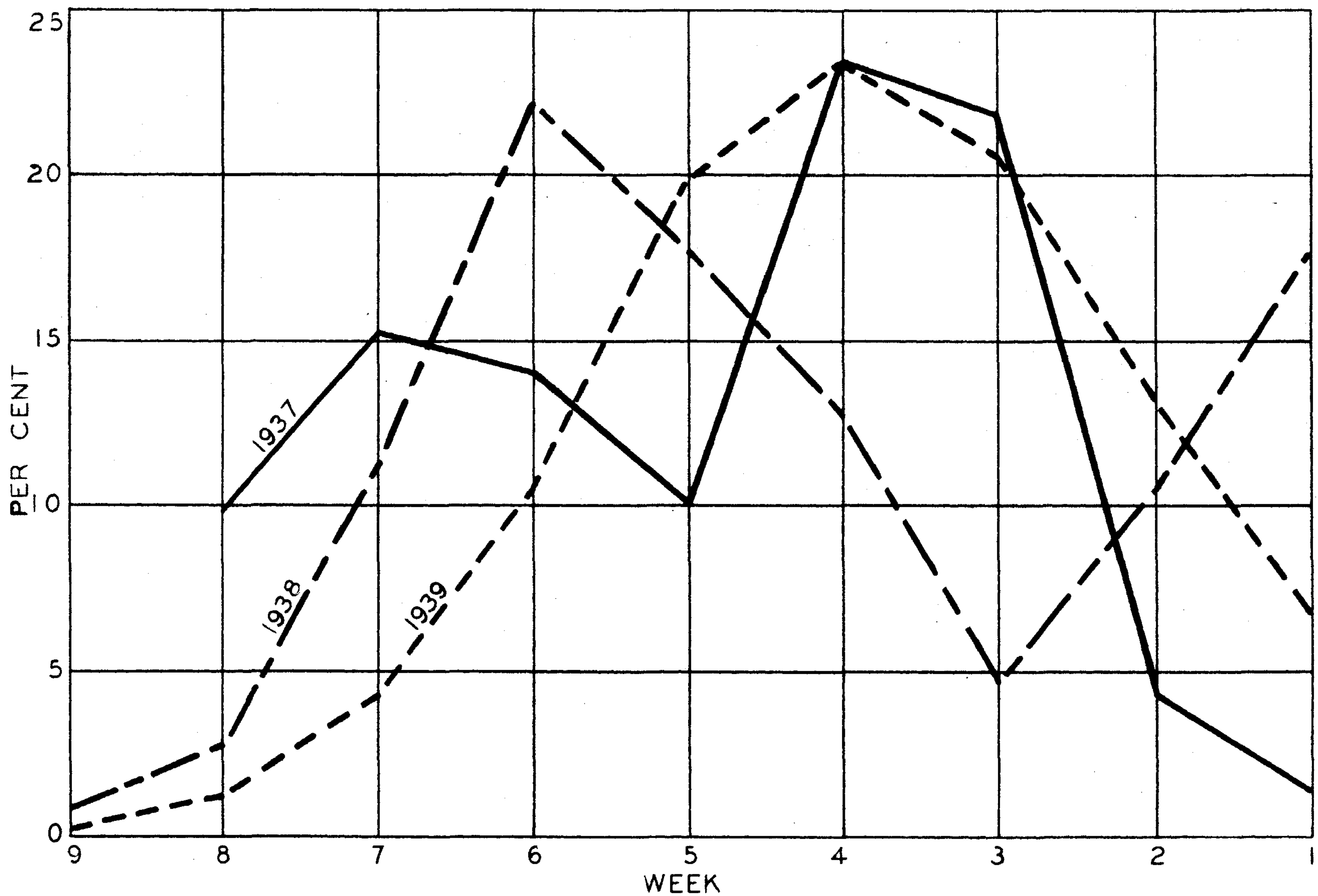

Fig. 5. Percent of plants dying each week, based on the total number killed by root rot.

records were reported by Jones and Thomas (1937) to show that small but consistent increases in yield were made on plants which died before August 5. The yields were not tested for significance since the treatments were not replicated. Studies made in later tests when the treatments were replicated showed that the experimental error was rather large. It is probable that the differences in yield between dusted and check plats in 1937 were not significant. The infestation records show that there was never a great difference in numbers of flea hoppers between the dusted and check plats (table 1).

Table 3. Effect of dusting on yield of plants killed at weekly intervals by root rot, 1937.

		Average pounds seed cotton per plant							
Died week ending	No. weeks dead	Field 1 Check	Field 1 Dust	Field 2 Check	Field 2 Dust	Field 3 Check	Field 3 Dust	Field 4 Check	Field 4 Dust
July 3*	7	.00582	.00630	.00059	.00140	.00106	.00061	.00611	.01007
July 10	6	.01821	.01790	.00384	.00578	.00608	.00461	.00405	.00549
July 17	5	.02322	.02128	.00924	.01253	.00736	.00834	.00845	.00721
July 24	4	.04724	.04485	.01893	.01755	.01184	.01788	.01209	.01582
July 31	3	.04035	.05689	.01270	.01777	.02242	.02298	.01918	.02062
Aug. 7	2	.08858	.10820	.04171	.04119	.05111	.05403	.03381	.05306
Aug. 14	1	.07792	.09188	.04594	.02938	.06421	.06379	.04632	.04418
Average		.04305	.04961	.01899	.01794	.02344	.02461	.01858	.02235

*Plants which died before this date produced no cotton.

The average yield per plant from those dying more than two weeks before the first picking was much less than from those dying later. The same general conclusions were reached regarding the weight of the bolls (table 22). Since the cost and ease of picking would be much greater from the plants dying early in the season than from normal plants, it is probable that most of the small bolls should be left in the field.

1938 Results

The investigations were continued at Cameron during 1938. Advantage was taken of some of the experiences gained during 1937, and the plat arrangements were changed. Gaines (1937) reported that small plats could be used successfully in flea hopper control experiments and that by a Latin square arrangement of the treatments the data could be analyzed for significance. The randomized block system was adopted, and the treatments were replicated three times in each of three fields. This arrangement had a decided advantage in that the significance of the treatments could be determined by the analysis of variance. By having a larger number of plats, a more even distribution of root rot plants was encountered. It is felt that this method of experimentation is far more satisfactory than the acre-sized plats with no replications that were formerly used by cotton insect research entomologists.

Crop conditions

The rainfall was 7.55 inches below the normal of 35.48 inches at Cameron (table 23). January, April, and June were the only months which received more than the normal precipitation. The deficiency of soil moisture was especially noticeable during July. Cotton failed to fruit in the top of the plant and only those bolls which set early matured. The losses due to dry weather, however, were partially offset by less than average damage from insects and root rot.

Insect infestation

Cotton flea hoppers were present in small numbers throughout the season (table 4). An incipient infestation developed in fields one and three. Sulfur dust was applied but damage was negligible on all plats. Flea hoppers are seldom destructive unless the cotton is growing rapidly.

Table 4. Effect of dusting on the cotton flea hopper infestation, 1938.

Week ending	Average number of cotton flea hoppers per 100 terminal buds*					
	Field 1		Field 2		Field 3	
	Check	Dust	Check	Dust	Check	Dust
June 18	5	7	4	4	20	19
June 25	15	17	8	9	11	8
July 2	11	4	18	18	18	9
July 9	9	8	8	5	5	5
July 16	8	8	4	6	2	3
July 23	3	3	2	3	1	2
July 30	2	2	1	0	0	0
Aug. 3	2	1	0	1	0	1
Weekly av.	6.9	6.2	5.6	5.8	7.1	5.9

*Average of 3 replicates.

Boll weevils became abundant in field 3 during the latter part of June, and more than 10 percent of the squares were found punctured at each examination during July (table 5). A light infestation, but of short duration, was present in fields 1 and 2.

Table 5. Effect of dusting on the percent squares punctured by the boll weevil, 1938.

	Average percent squares punctured*					
	Field 1		Field 2		Field 3	
Date	Check	Dust	Check	Dust	Check	Dust
June 18	-	-	-	-	4.7	3.3
June 23	4.3	0.7	1.0	3.7	3.7	2.7
June 30	0.7	0.3	5.0	5.3	27.0	22.3
July 4	19.7	17.0	19.7	16.3	36.3	28.7
July 9	18.0	11.7	13.3	14.7	32.0	17.0
July 14	8.7	3.3	6.0	4.0	18.3	5.7
July 19	4.0	2.0	7.3	2.3	16.0	10.0
July 25	5.7	5.3	8.7	6.3	26.7	17.0
Average	8.7	5.8	8.7	7.4	22.7	14.9

*Average of three replicates.

Dust applications were made in all fields, even though prospects were that controlling the few insects present might not result in increased yields. Three applications of calcium arsenate were made in all fields during July (table 6). The crop was maturing fast at that time and shedding was excessive. Dry weather had retarded vegetative growth and the plants were small. This permitted the squares which were punctured by boll weevils to fall on unshaded ground and a high mortality resulted.

Table 6. Date of dust applications and material used, 1938.

Date dusted	Field 1	Field 2	Field 3
June 16	--	--	Sulfur*
June 18	--	--	Sulfur
June 24	Sulfur	--	--
July 1	--	--	Cal. ars.
July 5	--	--	Cal. ars.
July 6	Cal. ars.	Cal. ars.	--
July 10	Cal. ars.	Cal. ars.	Cal. ars.
July 15	Cal. ars.	Cal. ars.	--

*Washed off by rain.

Cotton root rot

Root rot was killing some plants by June 11. The number of plants dying increased rapidly after that date and reached a peak during the week ending July 9 (fig. 5). Of the 8,578 plants killed by root rot during the season, 28 percent died during the last two weeks before the first picking, as compared with 5.66 percent dying during the same period in the 1937 tests. The percentage of plants killed by root rot is given in table 7. The loss of 44.28 percent of the plants in field 1 reduced the stand greatly as there were only 7,790 plants per acre, including those killed. That loss, however, was partially offset by increased yields from the living plants. Field 1 yielded 413 pounds of seed cotton from living plants and 20 pounds from dead plants on 0.75 acre (table 24).

Table 7. Effect of premature death of cotton plants on yield,* 1938.

Died week ending	No. weeks dead	Field 1 Plants dead	Field 1 Yield from dead plants	Field 2 Plants dead	Field 2 Yield from dead plants	Field 3 Plants dead	Field 3 Yield from dead plants	Average all fields Plants dead	Average all fields Yield from dead plants
		Percent plants killed and percent of total crop** produced by each group							
June 18	9	0.78	0.00	0.00	0.00	0.09	0.00	0.21	0.00
June 25	8	2.71	0.00	0.17	0.00	0.28	0.00	0.79	0.00
July 2	7	9.65	0.00	1.12	0.00	1.63	0.00	3.26	0.00
July 9	6	12.61	0.05	5.95	0.02	2.47	0.05	6.26	0.04
July 16	5	7.43	0.28	6.23	0.14	1.96	0.23	5.02	0.21
July 23	4	4.73	0.71	5.20	0.42	1.07	0.33	3.65	0.41
July 30	3	1.37	0.42	1.84	0.40	0.74	0.36	1.35	0.39
Aug. 6	2	2.26	0.92	4.54	1.88	1.54	1.18	2.97	1.33
Aug. 13	1	2.75	2.13	8.96	6.06	1.83	1.58	5.04	3.22
Total percent		44.29	4.51	34.02	8.92	11.61	3.73	28.55	5.61

*Average of 3 replicates.
**Yield was figured in percent of total yield from dead and living plants.

Results of insect control

The first picking was made during the week ending August 13. An average of 49.9 percent of the total yield was obtained at that time and the rest in the second picking. The cotton was picked from the living plants in all plats. Accurate records of the yield per plant were thus obtained from plants dying during each week and from living plants (table 8). There was no material difference in yield between the dusted and check plats. This was to be expected since both the flea hopper and boll weevil infestations were light, and any increases that might have resulted from dusting were later lost, due to dry weather.

Table 8. Effect of dusting on yield of seed cotton from living plants and plants killed by root rot,* 1938.

Died week ending	No. weeks dead	Average pounds seed cotton per plant					
		Field 1		Field 2		Field 3	
		Check	Dust	Check	Dust	Check	Dust
July 9**	6	.00027	.00023	.00012	.00009	.00095	.00128
July 16	5	.00237	.00230	.00085	.00080	.00511	.00931
July 23	4	.01111	.00735	.00298	.00333	.01546	.01935
July 30	3	.01626	.02242	.00879	.00802	.02182	.03437
Aug. 6	2	.02874	.03549	.01679	.01499	.04210	.03530
Aug. 13	1	.04922	.04792	.02589	.02536	.04617	.04138
Av. dead plants		.00717	.00608	.01090	.00940	.01689	.01722
Av. living plants		.103114	.11700	.04619	.06090	.05763	.05619

*Average of three replicates.
**Plants which died before this date produced no cotton.

The yield per plant (table 8) brings out strikingly the low yield secured from plants killed early in the season. The difference in yield between dead and living plants was greatest in field 1 where a high percentage of the plants died early in the season. In fields 2 and 3 the dead plants produced less than one-third as much seed cotton as the living plants. The yield per plant was in proportion to the age of the plants when they died.

The percentage of the total crop produced by each group of dead plants is shown in table 7. The most striking result brought out was the relatively small proportion of the crop produced on dead plants. Most of that yield was produced on the plants which died during the last two weeks. Only about 1 percent of the total yield was secured from plants which died before July 31. These figures are more forcefully brought out by the actual yield secured in each field (table 24).

The average weight per boll from dead plants was less than half that from living plants (table 22). The weight per boll decreased in relation to the age of the plants dying from root rot.

Quality of cotton lint

Samples of seed cotton were taken from each group of plants killed by root rot on dusted and check plats in each field. The size of the samples was limited to about two pounds or less since the plants dying early in the season produced a low yield. A sample was also taken from the living check plants at the time of the first picking. This cotton was stored for about six months before ginning (fig. 6).

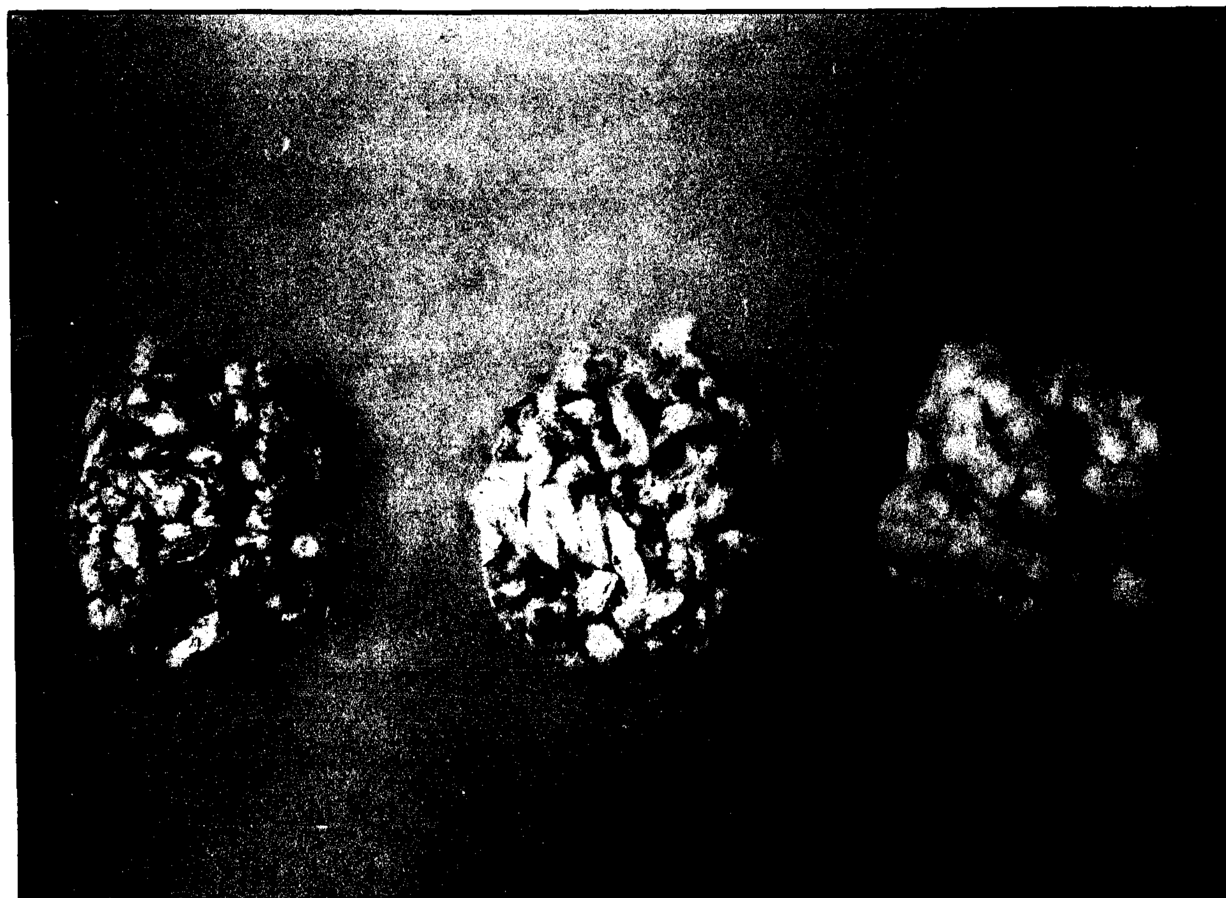

Fig. 6. Seed cotton on left picked from plants killed by root rot early in the season, center killed during mid-season, and right from plants living at the time of the first normal picking. Note the amount of trash present.

The samples were weighed and one pound, where that amount was available, was taken for ginning. The seed cotton was ginned with a hand gin made for handling small samples. The seeds and lint were weighed and the percentage of lint determined. The lint was graded and stapled by a licensed classer. Samples of lint were tested for breaking strength by the Chandler bundle and flat bundle methods. The maturity index and percentage maturity were also determined. Analyses of the seeds were made for protein, oil, ammonia, and moisture percentage. All of these determinations were made of samples from plants which were alive at the time of the first picking and from six groups of dead plants.

Grade. The grade of each sample was determined on the basis of the amount of foreign impurities, color, and preparation in ginning. One of the nine following grades, as established and described by the Universal Standards of American upland cotton grades, was given to each sample: Good Ordinary, Strict Good Ordinary, Low Middling, Strict Low Middling, Middling, Strict Middling, Good Middling, Strict Good Middling, and Middling Fair. Samples that were below Good Ordinary in quality were listed as Below Grade. The grade of each sample from dusted and check plats in three fields is given in tables 9, 10, and 11. The average grade of all samples is given in table 12.

The grade of the samples from plants that were dead for more than three weeks was about 2 grades lower than those dying later. All of the samples from plants dying during the last three weeks were of approximately the same grade, but averaged about one grade lower than samples from living plants. The average of the grades from all dead plants was two grades below that from living plants. There was no difference in grade between samples from dusted and check plats.

Table 9. Effect of dusting on the class of cotton produced on living plants and plants killed at weekly intervals by root rot. Field 1, Qualla variety, 1938.

	Check plats				Dusted plats			
			Character				Character	
Died week ending	Grade	Staple	Body	Uniformity	Grade	Staple	Body	Uniformity
July 9	B G	None	None	None	B G	1/2	Weak	Wasty
July 16	G O	1/2	Weak	Wasty	G O	1/2	Weak	Wasty
July 23	L M	13/16	Weak	Wasty	L M	3/4	Weak	Wasty
July 30	S L M	7/8	Weak	Wasty	S L M	7/8	Weak	Wasty
Aug. 6	L M	15/16	Sl. wk.	Sl. wasty	S L M brt.	15/16	Good	Good
Aug. 13	M	1	Good	Good	S L M brt.	15/16	Good	Good
Living*	M	15/16	Good	Good				

*These samples came from plants which were living at the time of the first picking.

Several factors may account for the low grade of cotton from dead plants. Plants killed by root rot possess dry and brittle bracks which break easily and make trashy seed cotton. These small fragments are hard to remove in ginning. The bolls are usually near the ground on plants dying early in the season and contain sand knocked from the ground by rains. The bolls open in a few days after the plants die and are exposed to the weather before the first normal picking is made. After the boll dies, the burr decays and causes the cotton to be stained, especially in immature bolls. Fragments from the seed coat (motes) are broken during ginning if the seed cotton is immature. If very immature, the small seeds will pass between the gin ribs and be included with the lint. Neps, or densely matted tangled fibers, will be formed when immature fibers are ginned. These are hard to remove and appear in finished yarn.

Table 10. Effect of dusting on the class of cotton produced on living plants and plants killed at weekly intervals by root rot. Field 2, Cliett variety, 1938.

	Check plats				Dusted plats			
			Character				Character	
Died week ending	Grade	Staple	Body	Uniformity	Grade	Staple	Body	Uniformity
July 9	B G	-	-	-	B G	-	-	-
July 16	B G	-	-	-	B G	-	-	-
July 23	S G O	13/16	Weak	Wasty	B G	13/16	Weak	Wasty
July 30	S L M	13/16	Weak	Wasty	S L M	7/8	Weak	Wasty
Aug. 6	S L M	29/32	Sl. weak	Sl. wasty	S L M	7/8	Weak	Wasty
Aug. 13	S L M	29/32	Sl. weak	Sl. wasty	L M	31/32	Good	Good
Living*	M	15/16	Sl. weak	Sl. wasty				

*These samples came from plants which were living at the time of the first picking.

<u>Staple</u>. The staple of the cotton samples was estimated in inches by a licensed cotton classer. The character of the body and uniformity of the fibers were determined in establishing the staple of each lot. The results of these studies are presented in tables 9, 10, and 11.

The staple length of the samples from living plants in all three fields was the same. In fields 1 and 3 the samples, from the plants which died during the week before the first picking was made, were longer than those from living plants. The length of the staple decreased in proportion to the time the plants were killed. The decrease was sharpest in samples which died more than three weeks prematurely.

Table 11. Effect of dusting on the class of cotton produced on living and dead plants killed at intervals by root rot. Field 3, Qualla variety, 1938.

		Check plats				Dusted plats			
				Character				Character	
Died week ending	No. wks. dead	Grade	Staple	Body	Uniformity	Grade	Staple	Body	Uniformity
July 9	6	B G	-	-	-	B G	-	-	-
July 16	5	B G	-	-	-	L M	13/16	Weak	Wasty
July 23	4	L M brt.	13/16	Weak	Wasty	S L M	13/16	Weak	Wasty
July 30	3	S L M	15/16	Good	Good	L M	15/16	Good	Good
Aug. 6	2	L M	31/32	Good	Good	L M	15/16	Good	Good
Aug. 13	1	L M	31/32	Good	Good	L M	15/16	Good	Good
Living*		L M brt.	15/16	Good	Good				

*These samples came from plants which were living at the time of the first picking.

The staple data presented in tables 9, 10, and 11 were combined in table 12 for convenience in interpretation. There was no consistent difference between dusted and check plats. The grade, staple, body, and uniformity were lowest from plants killed early in the season and highest from living plants.

Table 12. Effect of time of death on quality of cotton lint from dead and living plants.*

Died week ending	No. weeks dead	Grade	Staple	Staple character	
				Body	Uniformity
July 9	6	B G	1/2	Weak	Wasty
July 16	5	G O -	3/4 -	Weak	Wasty
July 23	4	L M -	13/16 -	Weak	Wasty
July 30	3	S L M -	29/32 -	Sl. weak -	Sl. wasty -
Aug. 6	2	S L M -	15/16 -	Good -	Good -
Aug. 13	1	S L M -	31/32 -	Good -	Good -
Living plants		M -	15/16	Good -	Good -

*Average of 6 samples from each group of dead plants and 3 samples from living plants.

Maturity and breaking strength. Studies were conducted on the maturity, breaking strength, and waste from samples taken from field 3. The fibers from plants dying early in the season were immature as indicated by the thickness of the walls and shape. A high percentage of the fibers in these samples was immature. These results were explained on the basis that the plants died with bolls in varying stages of development. Since there was not sufficient time for the secondary deposits to be laid down before the plant died, the fibers had thin walls and were flimsy.

The breaking strength of the fibers was determined by the Chandler bundle and flat bundle methods. These methods are described by Richardson, Bailey, and Conrad (1937), and a comparison of the two as used by Grimes (1937) was made. Since the results were almost identical, the data obtained by the flat bundle method is not given.

Table 13. Class and quality of lint and analyses of seed from plants killed by cotton root rot and from living plants. Field 3, Qualla variety, 1938.

Died week ending	Per-cent lint	Grade	Staple	Body	Uni-formity	Matur-ity index	Percent matur-ity	Breaking strength*	Cotton seed analyses Ammonia	Protein	Oil
									Percent	Percent	Percent
July 9	27.1	B G	-	-	-	.401	24.8	74.4	3.64	18.69	7.34
July 16	32.7	B G	13/16	Weak	Wasty	.456	23.9	76.4	3.77	19.38	7.85
July 23	38.1	L M brt.	13/16	Weak	Wasty	.565	36.4	79.4	3.97	20.41	9.12
July 30	40.8	S L M	29/32	Sl. weak	Sl. wasty	.694	49.3	79.7	4.06	20.88	10.89
Aug. 6	39.4	M	15/16	Good	Good	.728	56.1	77.2	4.27	21.94	13.23
Aug. 13	41.0	M	31/32	Good	Good	.795	64.7	75.5	4.36	22.41	14.82
Living**	40.4	L M brt.	31/32	Good	Good	.851	73.5	76.6	4.27	21.94	16.14

*Breaking strength in 1,000 pounds per square inch. Average of 10 tests, using the Chandler bundle method.

**Sample from plants living at time of first picking.

It was found that the strongest fibers came from the plants which were killed during the third and fourth weeks before the first picking (table 13). The breaking strength of individual fibers was not determined. Stroman, Taubenhaus, and Ezekiel (1935) found that fibers from root rot plants were coarser and less twisted than those from living plants. The cause of these fibers being coarse, as indicated by thickness and ribbon width, is not known. It was pointed out that these coarse fibers constituted only about 10 percent of the total yield from plants killed by root rot.

The percentage of waste was determined from two samples of cotton from dead plants and one from living plants. The waste of lint in samples taken from living plants was 23.5 percent, from plants killed during the third week 49.9 percent, and 71.8 percent in samples from plants killed six weeks before the first picking. The waste was largely due to the lack of uniformity in the staple length. It is of importance to the spinner to have the fibers as nearly the same length as possible.

<u>Percentage lint</u>. The percentage of lint in seed cotton samples was determined from all lots of dead plants and from living plants (table 14). These records were obtained by weighing the lint and by weighing the seeds ginned from a weighed sample. There was no consistent difference between the percentage of lint in samples from dusted and check plats. The percentage of lint was highest in seed cotton from living plants and lowest from those killed six weeks before the first picking.

Table 14. Percent lint in seed cotton from dead and living plants on dusted and check plats, 1938.

Died week ending	No. weeks dead	Field 1		Field 2		Field 3		Av. all fields
		Check	Dust	Check	Dust	Check	Dust	
July 9	6	33.3	33.3	-	33.3	26.3	33.3	32.1
July 16	5	29.1	32.2	35.0	36.6	32.9	32.6	33.0
July 23	4	33.0	33.7	34.9	37.2	37.2	36.8	35.5
July 30	3	37.0	38.3	38.1	40.0	38.7	39.7	37.9
Aug. 6	2	39.2	39.2	40.6	39.6	38.8	41.1	39.1
Aug. 13	1	38.1	39.2	41.2	39.2	39.2	39.6	39.3
Living plants*		39.8		40.6		39.8		40.1

*These samples came from plants which were living at the time of the first picking.

Analyses of cotton seeds

The seeds were analyzed from six samples of cotton picked from dead plants and one sample from living plants (table 15). It was found that the percentage of moisture and protein was about the same in all samples. There was an increase in ammonia and oil, depending on how late in the season the plants were killed. These figures agree with the findings of Rogers (1936 and 1937a).

1939 Results

After failing to encounter a high flea hopper infestation at Cameron in 1937 or 1938, the investigations were conducted during 1939 in another locality where this insect has been more destructive in the past. Port

Lavaca was selected since the Bureau of Entomology workers found high infestations for their control studies in that area almost every year since 1923. Cotton planters there reported that the flea hopper frequently destroys most of the young squares early in the season. The first flea hopper damage ever reported came from that area in 1897, and after 1919 the complaints were so frequent that the United States Department of Agriculture, Bureau of Entomology, established a field laboratory at Port Lavaca in 1923, and investigations have been continued there during most years since that time.

Port Lavaca is near the Gulf of Mexico in the Coastal Bend area. It is approximately 165 miles south of Cameron, where these investigations were conducted in 1937 and 1938. The seasons are almost a month earlier there than at Cameron. The first bale of cotton is usually picked there during the latter part of June. Rainfall is about the same at both places. The fields are large and nearly level, making uniform plat selections possible.

Crop conditions

The rainfall at Victoria, which is about 25 miles from Port Lavaca, was 14.86 inches below the normal of 35.66 inches. January, July, and September were the only months with rainfall above normal. This deficiency resulted in early fruiting, small sized plants, and excessive shedding late in June and in July. Hatching of the flea hopper eggs was delayed, and the infestation was never as high as reported in other years. Root rot was also less destructive than usual in fields where there was a deficiency of soil moisture. There was less rainfall on field 4 than on any of the others, and the above mentioned effects were more striking.

There was sufficient soil moisture until the middle of June, and the prospects at that time were that a large crop would be produced. Following this, there was a prolonged drouth which caused shedding of the fruit forms by June 25, and practically all young bolls which appeared after July 1 were lost. The drouth was broken during July when about eight inches of rain fell. This did some damage to cotton which was already open but started a new growth, and a top crop was made in fields where the boll weevil was controlled late in August.

Insect infestation

The flea hopper infestation in about 20 fields in the Coastal Bend area during the period April 30 to July 8 averaged 32.2 nymphs and adults per 100 buds. They increased from 15.5 during the week ending May 6 to 50.2 by June 10, and then decreased to 29.6 per 100 terminal buds by July 1. The infestation, depending largely upon the succulence of the cotton, was very spotted.

The selection of fields for experimental use had to be delayed until about May 15 in order to locate incipient infestations in fields where root rot was known to occur. Rains came about that time and the flea hopper eggs hatched, causing the infestation to increase rapidly. More than 25 nymphs and adults per 100 terminal buds were found in all check plats until June 24 (table 15). That infestation was sufficient to cause some damage, and justified the dust applications made according to the latest recommendations of the Bureau of Entomology and Plant Quarantine.

Plants in fields 1 and 2 showed typical injury from the flea hoppers (fig. 2). Field 4, which was in a dryer area, had a low infestation with practically no damage.

Table 15. Effect of dusting on the cotton flea hopper infestation, 1939.

Week ending	Average number of cotton flea hoppers per 100 terminal buds*							
	Field 1		Field 2		Field 3		Field 4	
	Check	Dust	Check	Dust	Check	Dust	Check	Dust
May 13	-	-	27.7	29.7	-	-	-	-
May 20	31.7	33.0	48.0	17.5	58.0	58.5	51.7	47.5
May 27	63.0	28.0	46.2	15.0	57.5	30.0	28.7	12.7
June 3	52.7	15.2	45.7	8.7	55.2	15.2	34.0	13.2
June 10	81.0	24.5	48.5	26.2	56.7	15.5	34.0	10.0
June 17	85.2	28.7	52.5	19.0	48.0	12.0	42.0	21.5
June 24	58.5	14.7	46.0	27.2	42.2	17.5	26.7	8.7
July 1	74.2	39.0	21.7	9.0	72.5	42.0	12.5	10.0
July 8	66.0	17.0	21.7	2.7	34.0	12.2	4.7	4.0
July 15	18.2	8.7			3.5	4.7	0.2	2.2
Wkly. av.**	58.9	22.0	39.8	15.7	47.5	18.6	26.0	10.3

*Average of 4 replicates.
**Average on dusted plats does not include the initial infestation.

All of the fields were dusted three or more times with the mixture of one-third calcium arsenate and two-thirds sulfur. It was not used after June 2 as it is well known that frequent and continued applications of calcium arsenate will result in an aphis infestation which will damage the cotton plants. One or more applications of sulfur were made in each field after that date (table 16).

Table 16. Date of dust applications and materials* used, 1939.

Date dusted	Field 1	Field 2	Field 3	Field 4
May 11	--	Mixture	--	--
May 16	--	--	--	Mixture
May 17	--	--	Mixture	--
May 18	--	Mixture	--	--
May 20	Mixture	--	--	--
May 24	--	--	--	Mixture
May 25	--	--	Mixture	--
May 26	--	Mixture	--	--
May 27	Mixture	--	--	--
May 31	--	--	--	Mixture
June 2	Mixture**	--	Mixture	--
June 6	Sulfur	--	--	--
June 8	--	Sulfur	--	--
June 12	Sulfur	--	--	--
June 13	--	--	--	Sulfur
June 23	--	Sulfur	Sulfur	--
June 24	Sulfur	--	--	--

*The mixture used consisted of 1/3 calcium arsenate and 2/3 sulfur. The sulfur was a standard brand.
**This application was partly washed off by rain which fell the same day.

Satisfactory control was obtained in all fields, as indicated by the reduction in numbers of flea hoppers on dusted plats (table 15). There were fewer than one-half as many flea hoppers on the dusted plats than on the checks throughout the season. Most of the fields continued to fruit heavily in spite of this infestation.

Only a few planters in that area dusted for flea hopper control that year. It was the general opinion that the cotton was fruiting sufficiently and that dusting would not be profitable, even though the infestation was fairly high.

Table 17. Effect of premature death of cotton plants on yield,* 1939.

Died week ending	No. weeks dead	Field 1 Plants dead	Field 1 Yield from dead plants	Field 2 Plants dead	Field 2 Yield from dead plants	Field 3 Plants dead	Field 3 Yield from dead plants	Field 4 Plants dead	Field 4 Yield from dead plants	Average Plants dead	Average Yield from dead plants
		Percent plants killed and percent of total crop produced by each group**									
May 20	9	0.03	0.00	0.02	0.00	0.07	0.00	0.00	0.00	0.02	0.00
May 27	8	0.56	0.00	0.24	0.00	0.58	0.00	0.00	0.00	0.34	0.00
June 3	7	2.17	0.00	0.59	0.00	2.01	0.00	0.22	0.00	1.19	0.00
June 10	6	2.58	0.00	2.06	0.00	6.06	0.00	0.66	0.00	3.07	0.00
June 17	5	6.88	0.09	3.38	0.00	11.58	0.04	0.82	0.00	5.89	0.03
June 24	4	6.19	0.59	5.31	0.09	13.05	0.80	0.82	0.01	6.86	0.34
July 1	3	5.66	1.24	5.09	0.49	11.51	3.13	1.12	0.13	6.30	1.15
July 8	2	3.61	1.43	4.25	1.26	5.84	3.41	0.83	0.25	3.89	1.53
July 15	1	0.91	0.55	3.06	1.76	2.42	2.12	0.63	0.30	2.00	1.21
Total percent		28.59	3.90	24.02	3.60	53.13	9.51	5.11	0.69	29.56	4.26

*Yield was figured in percent of total yield from dead and living plants.
**Average of 4 replicates.

Cotton root rot

Root rot began killing plants by May 10 (table 17) and increased gradually after that date until reaching a peak during the week ending June 24 (fig. 5). At the time of the first picking, a total of 40,585 plants was dead and 86,668 living on the combined experimental area of 4.67 acres. The stand count ranged from 17,473 to 36,947 plants per acre in the four fields.

Results of insect control

Cotton planters in that area make frequent pickings since they are afraid that tropical storms might damage the crop. The first picking in the experimental plats was made during the week ending July 15. The percent of the total crop gathered in each picking was as follows: first picking 31.2; second picking 38.9; and third picking 29.8.

The average yield per plant on dusted and check plats is given in table 18. The plants which died more than five weeks before the first picking did not produce any bolls which opened. After that time the yield increased in proportion to the stage of maturity reached when the plants died. The bolls were small on the plants which died early and larger on those dying late (table 22). The seed cotton from bolls produced on plants which died three weeks before the first picking was only about one-half as heavy as those from living plants. Many of the small bolls are left unpicked by planters, and are a total loss.

Table 18. Effect of dusting for insect control on yield of seed cotton from living and dead plants killed by root rot, 1939.

Died week ending	No. weeks dead	Average pounds seed cotton per plant*							
		Field 1		Field 2		Field 3		Field 4	
		Check	Dust	Check	Dust	Check	Dust	Check	Dust
June 17**	5	.00039	.00058	--	--	.00005	.00007	.00071	.00018
June 24	4	.00343	.00392	.00044	.00042	.00106	.00107	.00025	.00038
July 1	3	.00809	.00882	.00211	.00268	.00444	.00506	.00291	.00302
July 8	2	.01336	.01734	.00614	.00885	.00935	.01113	.00888	.00682
July 15	1	.02069	.02541	.01274	.01584	.01472	.01599	.01301	.01157
Av. dead plants		.00508	.00543	.00306	.00463	.00331	.00290	.00402	.00315
Living plants		.04767	.05649	.02746	.03450	.03092	.03612	.02724	.02832

*Average of 4 replicates.
**Plants which died before this date produced no cotton.

The percentage of the total crop picked in fields with varying amounts of root rot is shown in table 17. The yield from all dead plants was surprisingly small. Even in field 3 where more than one-half the plants died, they produced less than 10 percent of the total yield. Of that amount from dead plants, 5.53 percent came from plants which died during the last two weeks; and although not of as high quality as that produced by living plants, it was much better cotton than that which grew on the plants dying earlier (fig. 6).

The yield per plant, when the four replicates were averaged, was slightly higher in most groups of dead plants on the dusted than on the check plats. The yields varied considerably, however, in the different replicates. It was necessary to determine the significance of the yields

Table 19. Analysis of variance of yield per plant (4 replicates) from plants killed two weeks prematurely by cotton root rot, 1939.

Source of variation	Degrees of freedom	Field 1		Field 2		Field 3	
		Sum of squares	Mean squares	Sum of squares	Mean squares	Sum of squares	Mean squares
Blocks	3	.0000125459	.0000041820	.0000132965	.0000044322	.0000089875	.0000029958
Treatments	1	.0000277513	.0000277513	.0000117128	.0000117128	.0000004418	.0000004418
Error	3	.0000610948	.0000203649	.0000108505	.0000036168	.0000001337	.0000000446
Total	7	.0001013920		.0000358598		.0000095630	

Table 20. Analysis of variance of yield per plant (4 replicates) from plants killed one week prematurely by root rot, 1939.

Source of variation	Degrees of freedom	Field 1		Field 2		Field 3	
		Sum of squares	Mean squares	Sum of squares	Mean squares	Sum of squares	Mean squares
Blocks	3	.0001442106	.0000480702	.0001517671	.0000505890	.0000077885	.0000025962
Treatments	1	.0000167042	.0000167042	.0000539241	.0000539241	.0000017610	.0000017610
Error	3	.0001013194	.0000337731	.0000497248	.0000165749	.0000184499	.0000061500
Total	7	.0002622342		.0002554160		.0000279994	

Table 21. Analysis of variance of yield per plant (4 replicates) from plants living at the time of the first picking, 1939.

Source of variation	Degrees of freedom	Field 1		Field 2		Field 3	
		Sum of squares	Mean squares	Sum of squares	Mean squares	Sum of squares	Mean squares
Blocks	3	.0001528650	.0000509550	.0000704008	.0000234669	.0000254653	.0000084884
Treatments	1	.0001445850	.0001445850	.0000995460	.0000995460	.0000695021	.0000695021*
Error	3	.0005553251	.0001851084	.0000054682	.0000018227	.0000180640	.0000060213
Total	7	.0008527786		.0001754150		.0001130314	

*Significant at 5 percent level.

before reaching satisfactory conclusions. The analysis of variance was used, as described by Snedecor (1938).

The yield records secured in field 4, and those from plants which died in other fields more than two weeks before the first picking was made, were analyzed and the increase was not found to be significant. The analysis of the yields from cotton dying during the first and second weeks before the first picking is given in tables 19 and 20. There was no significant increase, which resulted from controlling the flea hopper, on either of these lots of dead plants, nor on any of those dying before that time.

Comparable yield records were made on plants which were living at the time of the first picking. The dusted plats in field 3 produced a significantly higher yield than the check plats, but the differences were not significant in fields 1 and 2 (table 21).

The actual yield secured from the dead and living plants in these fields is given in table 24. These records strikingly bring out the fact that even though a high percentage of the plants died, more than 90 percent of the total yield was picked from living plants. Since the plants which died more than two weeks before the first picking have small bolls which are difficult to pick, and the cotton produced is of a very low quality, it is evident that most of the plants killed by root rot were a total loss. Under the conditions existing in these fields during 1939, when controlling the flea hopper did not result in significantly increased yields on the dead plants, the yield must be considered very nearly the maximum obtainable. Had insects destroyed completely the crop produced on these dead plants, the yield in any of these fields would not have been reduced more than 10 percent (fig. 7).

Table 22. Average weight per boll produced on dead and living plants.

No. weeks dead*	1937 Field 1	1937 Field 2	1937 Field 3	1937 Field 4	1938** Field 1	1938** Field 2	1938** Field 3	1939*** Field 1	1939*** Field 4	Average
7	.00354	.00338	.00261	.00251	—	—	—	—	—	.00301
6	.00514	.00532	.00572	.00557	.00219	.00586	.00308	—	—	.00470
5	.00665	.00621	.00929	.00647	.00256	.00295	.00446	.00355	.00499	.00524
4	.01018	.00845	.00754	.00741	.00494	.00430	.00644	.00558	.00238	.00636
3	.01329	.00898	.00893	.00884	.00700	.00628	.00889	.00680	.00544	.00827
2	.01293	.01011	.01041	.01008	.00882	.00975	.01129	.00786	.00584	.00968
1	.01170	.00848	.01224	.01019	.01059	.00943	.01193	.00900	.00681	.01004
Av. dead	.00906	.00728	.00811	.00730	.00602	.00643	.00768	.00656	.00509	.00676
Living	—	—	—	—	.01484	.01187	.01593	.01553	.01100	—

*Plants dying more than 7 weeks before the first picking produced no cotton.
**Average of 3 replicates.
***Average of 4 replicates.

Table 23. Rainfall and departure from normal at Cameron, Texas, during 1937 and 1938 and at Victoria (near Port Lavaca), Texas, during 1939.*

Month	Cameron 1937		Cameron 1938		Victoria 1939	
	Rainfall	Departure	Rainfall	Departure	Rainfall	Departure
Jan.	5.18	+2.47	5.01	+2.30	2.29	+0.07
Feb.	0.31	-2.44	1.97	-0.78	0.83	-1.31
Mar.	2.55	-0.05	1.13	-1.47	0.19	-2.18
April	0.82	-3.48	6.33	+2.09	0.25	-2.81
May	0.62	-3.51	2.93	-1.20	1.68	-2.20
June	2.27	-0.42	3.51	+0.82	0.82	-2.36
July	1.78	-0.06	1.69	-0.15	5.00	+1.42
Aug.	3.36	+1.44	0.64	-1.28	1.46	-1.24
Sept.	1.07	-2.20	0.84	-2.43	5.88	+2.33
Oct.	3.27	+0.15	0.60	-2.52	0.20	-3.28
Nov.	3.86	+0.97	1.61	-1.28	0.17	-2.46
Dec.	4.73	+1.41	1.67	-1.65	2.03	-0.84
Total	29.82	-5.66	27.93	-7.55	20.80	-14.86

*Climatological Data, U. S. Department of Agriculture, Weather Bureau.

Table 24. Actual yield from plants killed by root rot and plants living at time of first normal picking.

Year	Field	Total picking area	No. dead plants	Dead plants	Living plants		Dead plants	
					Actual yield	Yield per acre	Actual yield	Yield per acre
		Acres		Percent	Pounds	Pounds	Pounds	Pounds
1938	1	0.75	3,061	44.29	413	551	20.23	27
1938	2	0.75	4,300	34.02	435	580	42.70	57
1938	3	0.75	1,218	11.61	528	704	20.67	27
1939	1	1.15	5,800	28.59	753	655	30.59	27
1939	2	1.21	10,457	24.02	1,030	851	38.44	32
1939	3	1.15	22,764	53.13	673	585	70.70	61
1939	4	1.15	1,564	5.11	806	701	5.57	5

DISCUSSION

The rainfall was below normal during the three years these investigations were made. Cotton plants under those conditions developed few vegetative buds and were small in size. They fruited early, but the deficiency of soil moisture caused excessive shedding and hastened maturity. These conditions were unfavorable for the flea hopper, boll weevil, and cotton root rot.

Incipient cotton flea hopper infestations were present each year when the fields were selected. The damage was negligible during 1937 and 1938. An infestation of more than 25 nymphs and adults per 100 terminal buds persisted in all checks for about six weeks during 1939, but the adequate control obtained, as indicated by infestation records, did not result in significantly increased yields on the dead plants. The boll weevil was present in low numbers during July 1938. The protection of squares obtained by calcium arsenate applications was offset by excessive shedding later in the season, and the yield was not increased by dusting. These results show that even though incipient infestations of the flea hopper and boll weevil are present and dust is applied, the yields may not be increased. Since neither of these insects materially reduced the yield on root rot plants during these years, it is apparent that by controlling heavy infestations, the yield under similar conditions would be no more than was made in these tests.

The present recommendations for flea hopper and boll weevil control are based on the supposition that a dust application should be made while the infestation is still low and before severe damage is done to the crop. When the infestation does not increase as expected, the control obtained may not result in increased yields. The first application should be considered as crop insurance.

It should be recalled that flea hoppers do not cause the blasting of squares that are more than about a week old. About 60 days are required for a fruit form to reach maturity after the square passes the stage when it is no longer susceptible to injury by flea hoppers. Control measures applied for this insect would not result in increased yields of mature bolls if applied within less than about 60 days before the plant dies. Boll weevils, bollworms, and other insects may attack large squares and bolls and reduce the yield on plants killed by root rot.

Root rot began killing some plants about the time the first blooms appeared each year. The seasonal distribution of dead plants was about the same during 1937 and 1939, but a higher percentage was killed during the last two weeks in 1938 than in the other years (fig. 5). Since these plants were more productive than those dying earlier, the losses due to root rot were somewhat lower during 1938 than they were during the other two years. It is therefore necessary to place considerable emphasis on the seasonal distribution of plants killed by root rot.

The yield per plant from all plants which died more than two weeks before the first picking was so low that they might as well be considered a total loss, especially since the bolls were small and the quality of the cotton low. Even those plants which died during the week preceding the first picking produced less than half as much as the living plants in all but one field.

The records from fields 1 and 2 in 1938 offer further proof of the importance of considering the seasonal distribution of root rot. In field 1 where 44.29 percent of the plants were killed, 4.51 percent died during the last two weeks. Only 4.67 percent of the total yield came from all dead plants. In contrast to this, field 2 had 34.02 percent of the plants killed, but 13.50 percent died during the last two weeks. The dead plants in this field produced 8.92 percent of the total crop. In all of the tests, the plants which died during the last two weeks produced more than half of the total amount picked from all dead plants. It appears, then, that all plants dying more than two weeks before the first picking are almost a total loss (fig. 7). This is especially true when the quality of the lint and seed from those plants is considered.

The percentage lint in seed cotton was found to increase slightly, depending on the time when the plants were killed, being highest in samples from living plants. Seven determinations were made on samples from living plants. Seven determinations were made on samples from each group of dead plants. The greatest differences in lint percentage were in samples from plants which died early in the season. Those from plants which died during the last two weeks were about the same. The grade, staple, body, and uniformity were found to be lowest in samples from plants killed early in the season and highest in those killed later.

It is obvious from the above discussion that root rot not only reduces the yield greatly, but also the quality of the lint and seeds. The losses were found to be directly proportional to the length of the time the plants were killed before reaching maturity. It is logical to conclude that under the conditions existing during the three years these tests were conducted that plants dying more than two weeks before the first picking are practically a total loss. Since insects did not materially reduce the yield of seed cotton from root rot plants, these yields might be considered the maximum obtainable under similar conditions. However, during seasons when a high percentage of the plants die late in the season, and after they have had time to mature a crop, insect control might be profitable on root rot cotton.

These findings and the recommendations made herein to planters apply only to seasons when the root rot distribution is similar to that encountered in these experiments, and to cotton which dies before the first normal picking is made. The value of insect control on living cotton was not the object of these studies.

These investigations were conducted during three seasons when the rainfall was below normal. That probably affected the insect infestations, abundance, and seasonal distribution of root rot, and yield from dead and living plants. The results might be different in years when the rainfall is above normal.

CONCLUSIONS

1. Although satisfactory control of the cotton flea hopper and the boll weevil was obtained by dust applications, as indicated by infestation records, the yield was not significantly increased on plants which were killed by root rot before the first picking was made. However, neither of these insects was very destructive on any of the undusted checks.

2. Since this yield from dead plants was not materially reduced by insect damage, it should be considered the maximum obtainable under similar conditions when insects are present but controlled.

3. The yield per plant was reduced approximately 50 percent when death occurred during the week immediately preceding the first normal picking and 75 percent when the plants died two weeks before the picking was made. These records included many small bolls with low quality lint and seeds, and should not be picked by farmers.

4. Since the yield produced by plants which died more than two weeks before the first picking was very low, the bolls small, and the quality of the lint and seeds low, it is concluded that those plants should be considered almost a total loss.

5. The lint and seeds from dead plants were of lower quality than from living plants, depending on the maturity of the plant when it was killed.

6. Root rot killed from 5.11 percent to 53.13 percent of the plants in the various fields, with an average of 29.39 percent in all fields during 1938 and 1939. The maximum percentage of the total crop produced

in any field by dead plants was 9.50, with an average of 4.70 in all fields. The plants which died more than two weeks before the first picking produced low quality cotton, which amounted to about one-third of the total yield from dead plants.

7. It is logical to conclude that insect control would be of little value in increasing the yield on cotton prematurely killed by root rot, under conditions similar to those existing when these experiments were conducted.

RECOMMENDATIONS TO PLANTERS

Satisfactory control measures to use against most of the major cotton insect pests are known. The profit to be made depends on the potential yield and the amount of reduction due to insects, if not controlled. Low yields from plants killed by root rot more than two weeks before the first picking cannot be increased materially by controlling insects. These plants produce only a small amount of low quality cotton when insects are not present.

The factor which determines the profit to be made from controlling insects on land where cotton dies from root rot is the yield from living plants regardless of the percentage of plants dying early in the season. If the yield from the living plants is sufficient for profitable cotton production and insects are damaging the crop, control measures should be used.

SUMMARY

These investigations were conducted at Cameron, Texas, during 1937 and 1938, and at Port Lavaca, Texas, during 1939. The three seasons were all deficient in rainfall, with the result that cotton plants were small and matured early. Continued drouths caused excessive shedding and reduced the yields each year. This loss was partially offset by less than usual damage caused by insect pests and root rot.

The field studies were conducted on three or four farms each year. Plats were selected where root rot was known to occur and where there was already present an incipient cotton flea hopper infestation. The treatments consisted of controlling the flea hopper and boll weevil by the recommended methods on one plat and leaving another as an untreated check. Four fields with the treatments not replicated were used in 1937. The treatments were replicated three times in three different fields in 1938 and four times in four fields in 1939.

The plants on all plats which died during each week were marked with a dated tag. The cotton on the dead plants was picked just before the planters made their first picking in the rest of the field. Records were taken on the number of bolls and weight of seed cotton picked from the plants which died during each week, and during the last two years from living plants.

Flea hopper and boll weevil infestation records were made at frequent intervals throughout the season. Insecticides were applied when needed, according to the latest control recommendations. The control obtained was determined by infestation counts and yield records.

The cotton flea hopper infestation was low in all fields during 1937 and 1938. During 1939 an average of more than 25 per 100 terminal buds was present on all check plats for about six weeks. Dust was applied for the control of this insect each year, but protecting the young squares did not result in a material increase in the yield on the plants killed by root rot. Boll weevils did practically no damage during 1937 or 1939. There was an incipient infestation during 1938, but the control obtained did not result in a material increase in yields on the dead plants. Excessive shedding, due to a deficiency of soil moisture, partly accounts for the failure to make increased yields where insects were present but controlled. It appears, then, that the yields secured were as high as could be obtained when insect damage is prevented under similar conditions.

The yield was determined on 59,337 plants which were killed by root rot. All of these plants produced surprisingly low yields. Those which died during the week preceding the first picking in 1938 and 1939 produced only about one-half as much as the living plants, while those dying two weeks earlier were only about one-fourth as productive. The average weight of all bolls from dead plants was approximately half that from living plants. The weight decreased according to the length of time that the plant died before the first picking was made.

The percent of plants dying in each field ranged from 5.11 to 53.13. The percent of the total crop produced by these plants varied from 0.69 to 9.51. Even in fields where more than one-half the plants died, less than 10 percent of the total yield was produced by these plants. The average from all dead plants during 1938 and 1939 was 4.7 percent of the total yield.

Samples of seed cotton from dead and living plants were taken during 1938 for quality determinations. It was found that the percentage of lint in seed cotton, grade, staple, body, uniformity, maturity of the fibers, percentage waste, and ammonia and oil in the seeds was lower from plants dying early in the season and higher from those dying later or from living plants.

The conclusion reached was that insect control would be of little value in increasing the yield of cotton on plants killed by root rot before the first normal picking. This was based on the following findings: (1) Since dusting for the control of the flea hopper and boll weevil did not result in increased yields, it was assumed that these insects did not materially decrease the yield. No higher yields could be secured, under similar conditions, when insects are present but controlled. (2) Plants killed more than two weeks before the first picking were almost a total loss, and the yields were reduced more than 50 percent when plants died during the two weeks preceding the first normal picking. The yield from all dead plants in seven fields averaged 4.70 percent of the total crop. (3) The quality of the seeds and lint was reduced by premature death of the plant. (4) Insect control, on plants killed by root rot, would therefore benefit only a small portion of the total yield, even where half of the plants die from root rot.

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ACKNOWLEDGMENTS

The writer is indebted to Dr. J. C. Gaines, Entomologist, Texas Agricultural Experiment Station, for assistance in planning the experiments, advice regarding the interpretation of the data, and for criticism of the manuscript. Thanks are extended to Dr. F. L. Thomas, Chief of the Division of Entomology, Texas Agricultural Experiment Station, for suggesting the problem and permitting its use as a thesis. The following employees of the Division of Entomology assisted in taking field records: Dr. M. J. Janes, Mr. T. B. Randolph, Mr. F. A. Cowan, and Mr. Kenneth Roemer.

Full credit is given the following people for the technical work performed by each: Mr. D. T. Killough, Agronomist, Texas Agricultural Experiment Station, ginned the samples and determined the percentage lint in seed cotton; Mr. J. G. Powers of the Textile Department, Texas A. & M. College, classed the lint; Miss Mary Anna Grimes, Textile and Clothing Specialist, Texas Agricultural Experiment Station, determined the maturity, waste, and breaking strength of the lint; and Dr. C. H. Rogers, Plant Pathologist, Texas Agricultural Experiment Station, conducted the seed analyses.

Thanks are given to Dr. H. M. Harris, Associate Professor, Department of Zoology and Entomology, Iowa State College, for guidance and suggestions regarding the presentation of this manuscript.

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